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(54) Control of hydraulic booms

(57) Automatic electronic control means are for the movement of hydraulic boom(s) or e.g. in tunnel-boring and road-header machines. The automatic boom control is in accordance with stored information relating to a desired path of boom movement by means of hydraulic control valves connected in the hydraulic control circuit of the boom and uses feedback control.

The boom includes a turret rotatable about a vertical axis, and a jib mounted on the turret for rotation about a horizontal axis. Two mechanically operated hydraulic control valves are connected in the hydraulic control circuit for the independent control of the movements of the turret and jib, and further mechanically operated control valve(s) control their speed of movement about their respective axis.

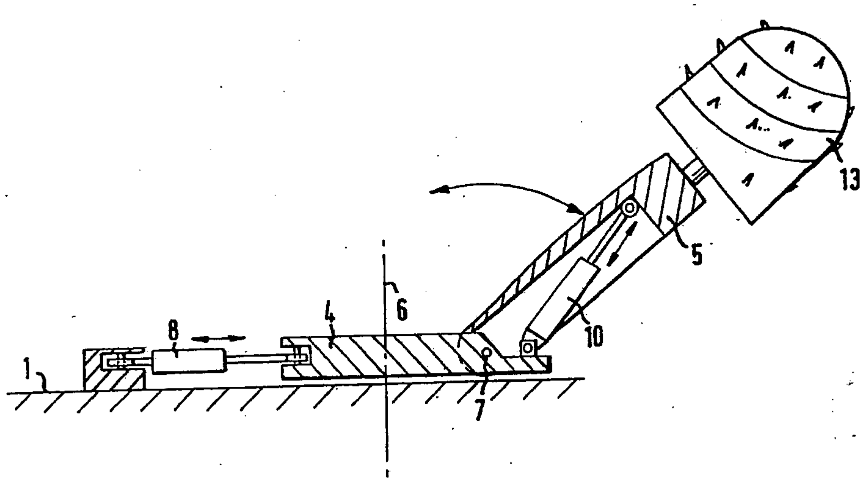

FIG.2

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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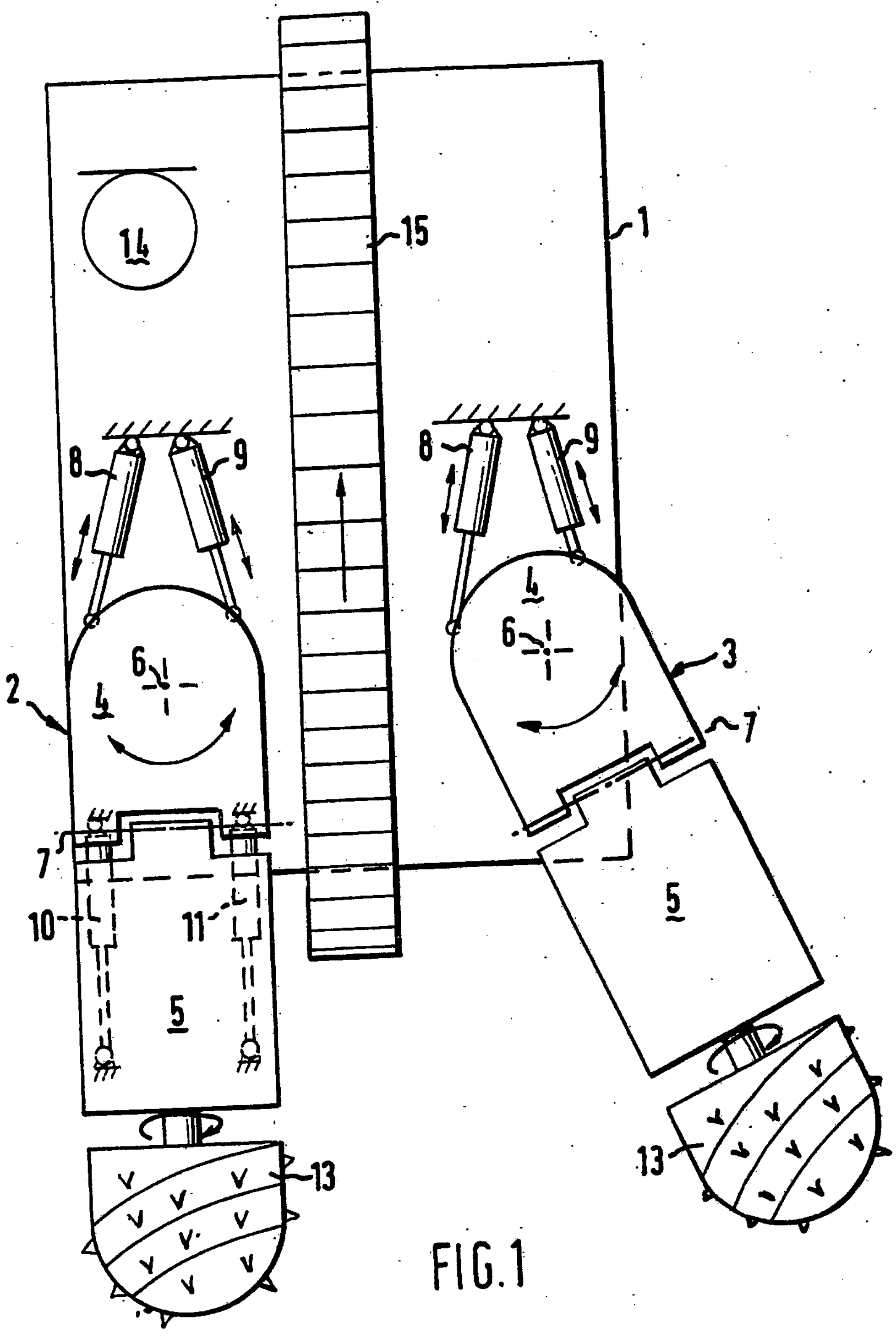


FIG.1

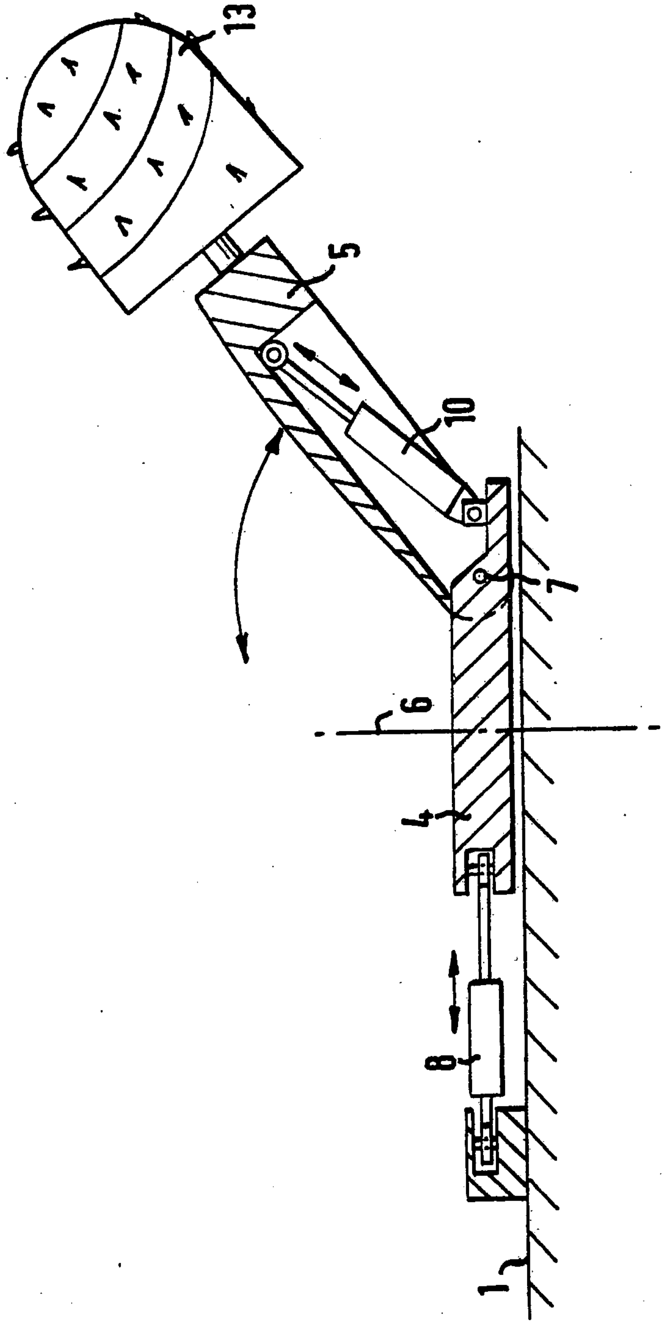
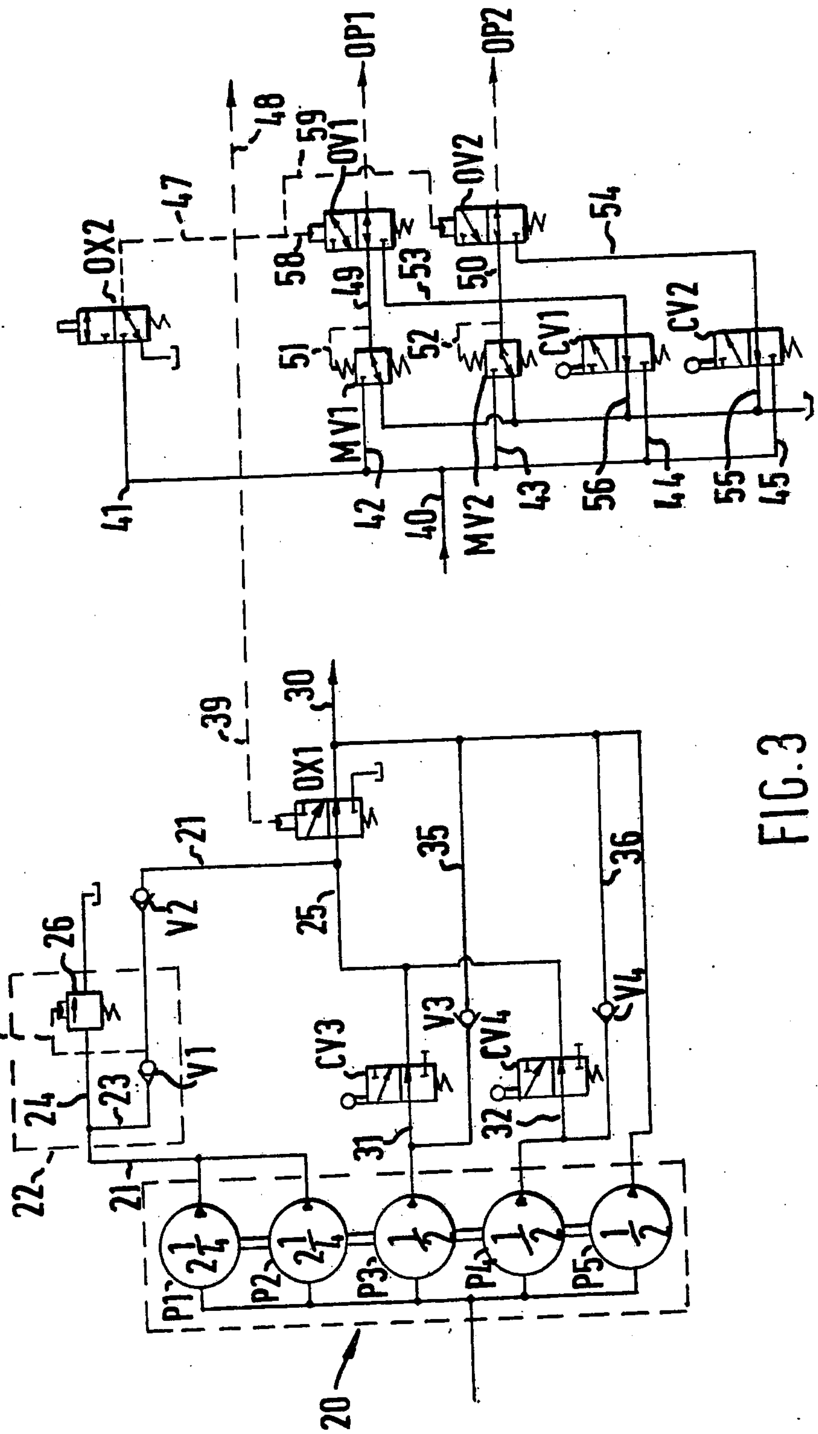


FIG.2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OP2
OX2
OX1
OV1
OV2
MV1
MV2
CV1
CV2
CV3
CV4
V1
V2
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P1
P2
P3
P4
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FIG. 3

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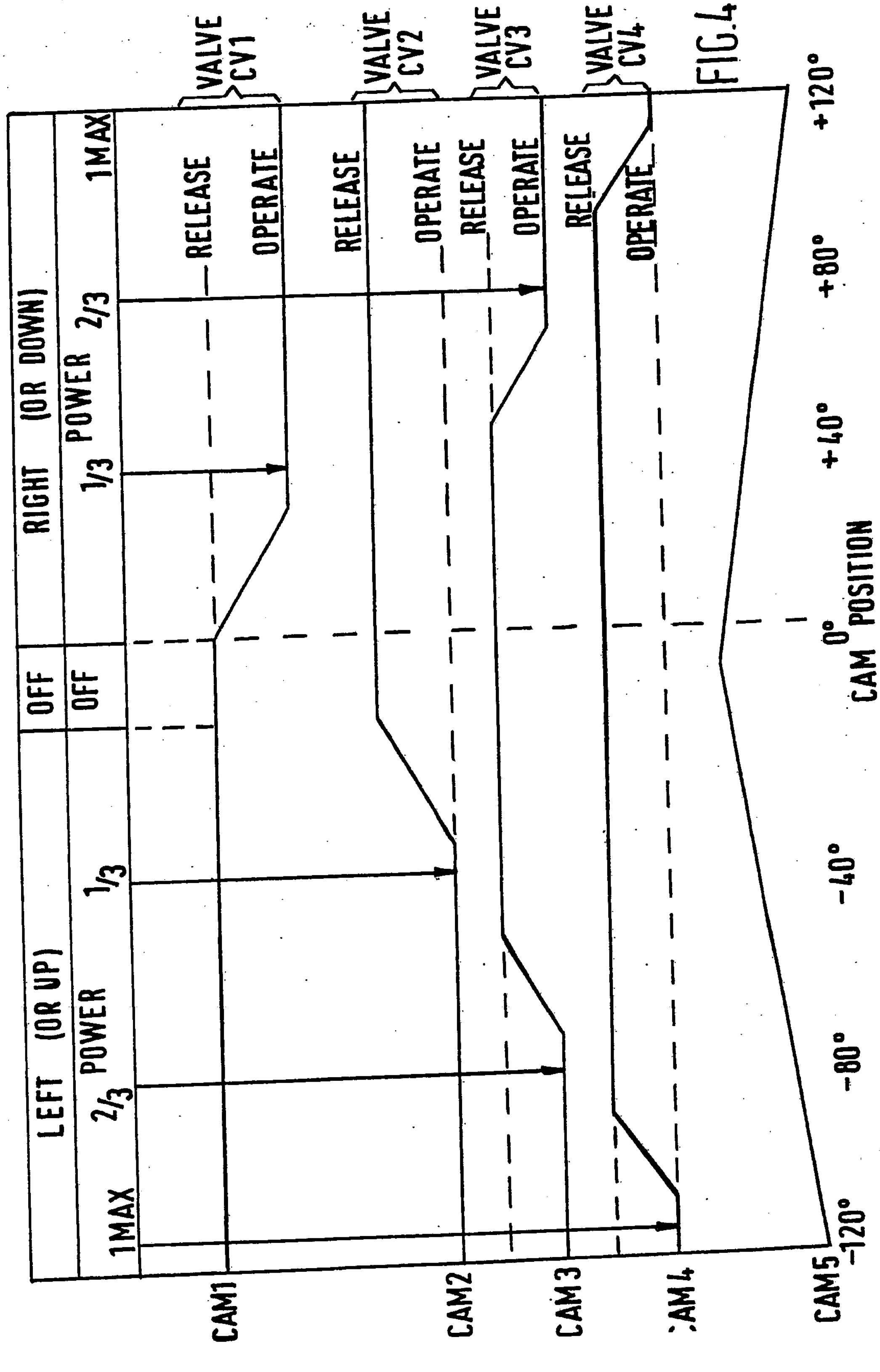

FIG.4

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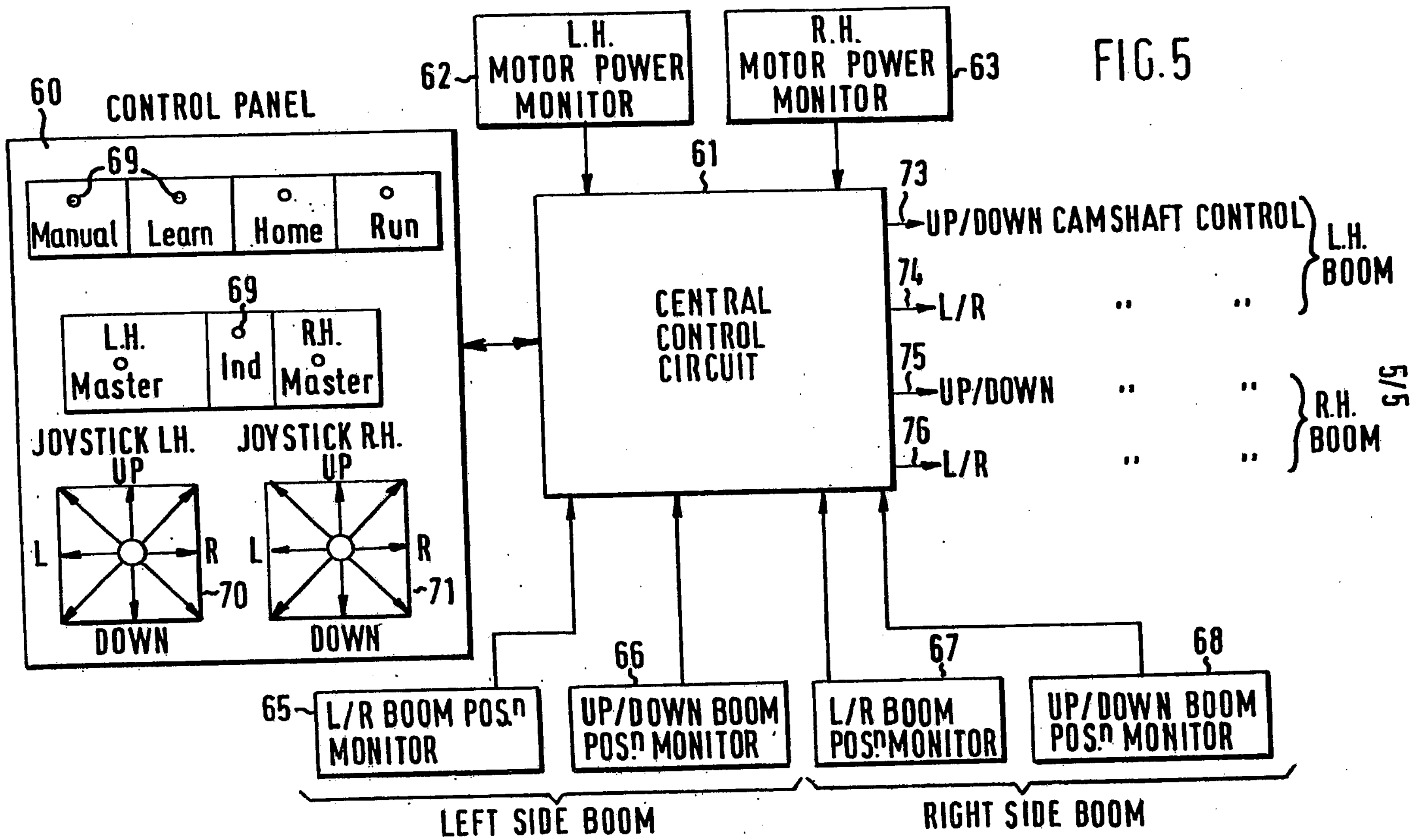
FIG.5



SPECIFICATION

Improvements in or relating to the control of hydraulic booms

This invention relates to the control of hydraulic all-actuated booms, particularly in tunnel-boring or cutting machines and so-called "road header" machines.

Such machines typically comprise one or more hydraulic booms mounted on a mobile carriage. The or each boom carries at its free end a rotary rock-cutting head. The or each boom is pivotally mounted on the carriage to provide at least two degrees of freedom for the movement of the cutting head. This is normally achieved by a boom comprising a first boom portion pivotable relative to the carriage about a first axis, e.g. a turret pivotable about the vertical axis, and a second boom portion pivotable relative to the first portion about a second axis perpendicular to the first axis, e.g. a jib pivotable relative to the turret about a horizontal axis.

Movement of the turret and jib portions of the boom about their respective axes is effected by hydraulic cylinders or rams usually under the direct control of a joystick. In the case of a multiple boom machine, each boom is independently controlled by a separate joystick. In twin-boom machines, the two booms are mounted at the front on either side of the carriage and project forwardly therefrom. In operation, to drill a tunnel section in a rock face for example the two booms are moved side-by-side to a central straight-ahead position. The carriage is then inched forward with the booms fixed and the cutting heads rotating such that the two heads are embedded to the required depth in the rock face. This operation is called "sumping in". The machine is then stabilised for example by hydraulically operated legs, and the operator then manipulates the two booms using the joystick controls to cause the two cutting heads to describe desired cutting paths to cut a tunnel section in the rock face to a depth of the original sumping-in bore. These cutting paths usually comprise multi-directional movements in mirror-imaged halves of the cutting region leaving a central wall of material between the two halves in the region of overlap of the two booms. This central wall is usually then removed by one of the booms while the other is held safely out of the way. An operator will usually repeat substantially the same boom movements in cutting each section of the tunnel.

Road-header machines of the above kind suffer from a number of drawbacks, particularly arising from the manual control thereof. During operation, the operator will often not be able to observe the rock face clearly due to dust clouds which must be allowed to settle to enable periodic inspection of the rock face and to the relatively remote position for safety reasons of the operator well behind the cutting booms. Further, the working environment of such machines e.g. in a hot coal mine, is not conducive to the considerable powers of concentration required to control two independently operating booms.

During cutting, the operator must ensure as far as he is able that the reaction forces resulting from the applied cutting pressure of the two booms are substantially symmetrical to reduce the risk of instability, and he must also ensure that, when cutting with only one boom, the other boom is held safely out of the way.

Accordingly, an operator is limited in the length of time during any working shift that he is actually working the machine.

It is an aim of the present invention to provide control means for one or more hydraulic booms which enables at least some of the above disadvantages to be overcome or at least substantially reduced.

According to the present invention, automatic electronic control means for a hydraulic boom includes means for automatically controlling the movement of the boom in accordance with stored information relating to a desired path of movement of the boom by means of mechanically operated hydraulic control valves connected in the hydraulic control circuit of the boom.

Preferably, the said mechanically operated hydraulic control valves are solenoid actuated or proportional valves controlled by electrical signals from the control means.

The hydraulic boom may include a first portion pivotally mounted on a support for rotation about a first axis, and a second portion pivotally mounted on the first portion for rotation about a second axis perpendicular to the first. The first portion may comprise a turret pivotable about a vertical axis, the second portion then comprising a jib portion pivotable relative to the turret about a horizontal axis. The hydraulic control circuit for the boom may include means for independently controlling the pivotal movements of the first and second portions thereof about their respective axes. In this case, the automatic control means may include two mechanically operated hydraulic control valves connected in the hydraulic control circuit of the boom for controlling the movements of each of the two boom portions, one for each direction of movement of that boom portion about its respective axis. One or more further mechanically operated control valves may be included for controlling the speed of movement of each boom portion about its axis.

The mechanically operated hydraulic control valves for each of the first and second portions of the boom may be controlled by a respective bank of cams conveniently mounted on a common camshaft. Thus control of the boom effectively reduces to controlling the rotation of two cam-shafts, one for each axis of movement, the direction of movement of the boom in each axis conveniently being controlled by the direction of rotation of the relevant camshaft. The speed of movement in the relevant direction may also be determined by the extent of movement of the camshaft in the relevant direction.

The control means may be adapted for the co-

ordinated control of two or more booms for example in a multiple-boom road-header or tunnel cutting machine. In such a system, the stored information may comprise information relating to the desired paths of movement of each boom, and preferably also the desired relative positions of the booms or of pairs of booms, during such movements.

The control means may also include means for monitoring the positions of the or each boom, and feed-back means for comparing the actual position of the boom(s), as sensed by said monitoring means, with the desired position of the booms as determined by the stored information, whereby to control the movement of the boom(s) to maintain correspondence between the actual and desired boom positions.

The control means may also include means for deriving said stored information by monitoring the movements of the boom(s) during a "teaching run" and storing information relating to the boom positions during the teaching run. The boom(s) may thus be controlled to repeat a desired cutting path selected by the operator during the teaching run. In a multiple boom machine, two or more booms may be automatically controlled from stored information derived from a teaching run using only one boom. For example, a pair of booms may be made to follow mirror image paths using information derived from the teaching run using only one boom. This has advantages in maintaining symmetrical reactive forces during a cutting operation for example.

The above and other features and advantages of the present invention will become apparent from the following description of a control means in accordance with the invention for use in a twin-boom road header machine, given by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic plan view of a twin-boom road header machine;

Figure 2 is a schematic elevational view of part of the road-header machine shown in Figure 1;

Figure 3 is a schematic diagram of part of a hydraulic circuit for controlling a hydraulic boom by control means in accordance with the present invention;

Figure 4 is a cam diagram illustrating the operation of part of the control means in accordance with the present invention; and

Figure 5 is a schematic block diagram of a control means in accordance with the present invention.

With reference to the drawings, Figures 1 and 2 schematically illustrate a twin boom road-header or tunnel-cutting machine comprising a chassis or carriage 1 which can be driven at slow speed on wheels (not shown) and which also incorporates at each corner a hydraulically operated stabilising leg (not shown) by means of which the machine can be stably supported on even or uneven ground during cutting operations.

Mounted towards the front, and on either side of the carriage 1 is one of a pair of identical booms 2, 3 each of which comprises a turret 4 and a jib 5.

Each of the boom turrets 4 is pivotally mounted on the carriage for pivotal movement about a vertical axis 6 under the control of a pair of opposed or push-pull hydraulic rams 8, 9. Each of the boom jibs 5 is pivotally supported on its turret 4 for pivotal movement about a horizontal axis 7 under the control of a pair of double-acting hydraulic rams 10, 11.

Projecting from the free end of each boom jib 5 is a power-driven rotary rock-cutting head 13.

Independent manual control of each of the booms 2, 3 is effected by separate joystick controls from a central position 14. In known manner, sideways movement of a joystick will actuate the hydraulic rams 8, 9 of the associated boom to cause the turret 4 to rotate in the direction corresponding to the direction of sideways movement of the joystick, while vertical movement of the joystick will actuate the rams 10, 11 of the associated boom to raise or lower the jib 5. Intermediate positions of the joystick produce simultaneous pivoting of both turret and jib to produce movement of the cutting head in a "diagonal" direction corresponding to the position of the joystick.

As a preferred feature, material removed from the rock face during a cutting operation (described earlier) is cleared by means of a conveyor 15 passing centrally between the two booms 2, 3.

Figure 3 shows part of the hydraulic circuit for controlling the movements of one boom about one of its axes in accordance with the invention. For the purposes of this description, reference will be made to the hydraulic circuit controlling the rotation of the turret portion 4 of one of the booms. The corresponding circuit for controlling the up/down movement of the jib portion 5 is substantially identical. Thus, the control system includes for such circuits one for each axis of movement of each of the two booms.

As shown, the circuit comprises a flow-divider 20 with five pumps P1 to P5 whose inputs are each connected to a common source (not shown) of hydraulic fluid. Two of the pumps P1, P2 each have a fixed capacity representing, e.g. 2-1/4 units of hydraulic power and their outputs are connected together into a common line 21 which provides the input to a pressure relief unit 22. Within the unit 22, the line 21 divides into two lines 23, 24, the first of which is connected via a pair of series-connected non-return valves V1, V2 to the input line 25 of a pressure-controlled shut-off valve OX1.

The other line 24 is connected to a central fluid reservoir via a pressure control valve 26 which is actuated via a pilot line 28 by the pressure in line 23 between the two non-return valves V1, V2. Thus when pressure in line 23 exceeds a predetermined value, which will occur when value OX1 is closed, valve 26 opens to relieve the pressure to an acceptable level.

The three remaining pumps P3, P4, P5 of the

flow divider 20 each have a flow capacity representing, e.g. 1/2 unit of hydraulic power. The outputs of pumps P3 and P4 are each connected in lines 31, 32 through respective cam-operated shut-off valves CV3, CV4 to the input line 25 of the valve OX1. Closure of either of valves CV3, CV4 forces the hydraulic fluid from their respective pumps P3, P4 along by-pass lines 35, 36 via respective non-return valves V3, V4 and into the output line 30 from shut-off valve OX1. The output of pump P5 is connected directly to the output line 30 of valve OX1 which is pressure-controlled via a pilot line 39.

The part of the hydraulic circuit so far described controls the power applied to the hydraulic rams 8, 9 via output line 30.

The hydraulic circuit of Figure 3 also includes a part for controlling the direction of movement, left or right of the turret 4 under the control of the rams 8, 9 powered by the first part of the circuit. This part of the circuit shown in the right-hand side of Figure 3, is powered from a separate source (not shown) via an input line 40 which divides into five pipe-lines 41 to 45. One of these lines 41 is connected to the input of a manually controlled master switch-over valve OX2 for switching the boom control between "manual" and "electronic". The output of valve OX2 comprises a pilot control line 47.

Two others, lines 42, 43 are connected to ports of respective manually operated two-way directional flow control valves MV1, MV2. A second port of each of these valves MV1, MV2 is connected to the central fluid reservoir while a third port of each is connected via lines 49, 50 to respective ports of a pair of pressure-controlled valves OV1, OV2. Each of the valves MV1, MV2 is also affected by the pressure in lines 49, 50 via respective pilot control lines 51, 52 which pressure control opposes the manual control.

A second port of each of the valves OV1, OV2 is connected to a respective output pilot control line OP1, OP2 while a third port of each is connected via line 53, 54 to a port of a respective one of a pair of cam-actuated valves CV1, CV2. A second port of each of these valves CV1, CV2 is connected to the central fluid reservoir via lines 55, 56 and a third port of each is connected to a respective one of the two lines 44, 45 connected to the input line 40.

Each of the valves OV1, OV2 is pressure-controlled via pilot control line 58, 59 which each communicate with the output 47 of the master switchover valve OX2 as does the pilot control line 39 for the valve OX1. The output pilot line 47 from valve OX2 is also connected, via output pilot line 48, to the pilot control lines of corresponding valves (OX1, OV1 and OV2) of the other identical circuits in the machine. Thus valve OX2 provides simultaneous switch-over from manual to electronic control for both booms.

Output pilot control lines OP1, OP2 control the direction of movement, left or right of the turret by providing servo control to a spool valve (not shown) through which the power output from ne 30 is applied to the hydraulic rams 8, 9 in known manner.

As shown, the circuit is set for manual control in which the master valve OX2 is closed such that there is no pressure in pilot line 47 and communicating pilot lines 39, 58 and 59, as well as in the corresponding pilot lines of the other three identical circuits of the machine via pilot output line 48.

In this manual mode, valves OX1, CV1 and CV4 are open, and the power flow provided at output 30 is provided by all five pumps P1 to P5 providing a maximum power output of 6 units of hydraulic power. In this mode, the operation of the left-hand side of the control circuit is entirely conventional, corresponding to a conventional system having a first pump of 5-1/2 power units capacity delivering power to output line 30 via the pressure relief unit and a second pump of 1/2 power unit delivered direct to the output 30.

The operation of the right hand part of the Figure 3 circuit is also conventional in the manual mode, corresponding to a circuit comprising only manually operated valve MV1, MV2 coupled directly to output pilot lines OP1, OP2 respectively, valves MV1, MV2 in this mode being selectively operated to control the direction of movement of the boom turret 4 under joystick control, in known manner.

Additional valves CV1 to CV3 and OV1, OV2 are provided for the purposes of an electronic control mode selected by opening the master switch-over valves OX2. This pressurises the pilot line 47 feeding pilot lines 39, 48 and 59 and, via output line 78 the corresponding pilot lines of the three other identical circuits. Pressure in these pilot lines causes OX1 to shut off thereby initially reducing the power available through output 30 to half a unit from pump P5, up to a maximum of 1-1/2 units by selective actuation of cam-operated valves CV3, CV4 to force flow from pumps P3, P4 via by-pass lines 35 and 36 to output 30. This enables the power output pressure to be increased in steps of 1/2 unit up to the maximum of 1-1/2 units.

Actuation of valve OX2 also actuates valves OV1, OV2 via pilot lines 58, 59 thereby cutting out the manual control valves MV1, MV2 and simultaneously bringing in the cam-operated valves CV1, CV2 in their place. Valves CV1, CV2 thus control the interconnection of the pressure of input lines 40 to the respective output pilot lines OP1, OP2 via valves OV1, OV2 in substantially the same manner as the valves MV1, MV2 do when in the manual mode, the difference being that valves CV1, CV2 are cam-operated.

It will thus be appreciated that in this electronic mode, selective actuation of the four cam-operated valves CV1 to CV4 can be used to control the direction and speed of movement of the boom turret 4 about the vertical axis.

These four valves CV1 to CV4 are mechanically actuated in accordance with the invention through cam followers by means of a set of four cams CAM1 to CAM4 fixed on a common

camshaft together with a spring biased return cam CAM5. The operation of these cams is schematically illustrated in the cam diagram of Figure 4 which is largely self-explanatory.

In the central OFF position of the camshaft, all four valves CV1 to CV4 are in the states shown in Figure 3. Clockwise rotation of the camshaft from the central OFF position (0°) to the +40° position causes CAM1 to actuate valve CV1 causing the boom to rotate to the left, powered by the 1/2 unit (1/3 maximum power) power output of the pump P5. Continued rotation of the cam to the +80° position causes CAM3 to actuate (close) valve CV3 adding a further 1/2 unit of power from pump P3 to output 30 to provide 2/3 maximum power to the hydraulic rams 8, 9. Further movement to the +120° limit causes CAM4 to actuate (close) valve CV4 adding a final 1/2 unit of power from pump P4 to output 30 giving a maximum of 1-1/2 units of power for rams 8, 9.

Correspondingly, operation of the circuit on rotation of the camshaft in an anti-clockwise direction from the OFF position is identical, with the exception that CV2 is operated instead of CV1 causing the boom to rotate left, instead of right.

Upon failure of the camshaft drive, the camshaft automatically returns to the safe zero position under the influence of the spring-biased return cam CAM5 arresting movement of the boom. Mechanical operation of the boom control valves CV1 to CV4 in this manner under the control of an electronically controlled drive motor is considerably safer and more reliable than using equivalent solenoid-operated control valves.

As already explained, each of the two axes of movement of each of the two booms of the machine is controlled by an identical control circuit, and the four cam shafts which control these four circuits are controlled from a micro-processor control unit, the operation of which will now be described with reference to Figure 5.

The microprocessor control unit includes a control panel 60 which has a two-way interface with a central microprocessor control circuit 61. This circuit 61 is connected to receive input signals from a pair of motor power monitors 62, 63 which provide information on the power being consumed by each of the motors driving the rotary cutting heads 13 on the end of each boom 2, 3; and input signals from each of four boom position sensors 65, 66, 67,68 providing information on the position of each boom. These sensors comprise for each boom one sensor 65, 67 which measures the relative displacement between the turret 4 and the carriage 1, and one sensor 66, 68 which measures the relative displacement between the jib 5 and the turret 4. In the present embodiment, the sensors measure the extension of one or both of the relevant hydraulic rams 8, 9; 10, 11.

The control circuit 61 has four outputs 73 to 76 providing output signals for controlling each of the four camshafts associated with the four identical hydraulic boom control circuits (Figure 3). These signals control the direction and extent of movement of each of the camshafts via an electric motor (not shown) to provide the necessary movement control of both booms.

The control panel 60, which may be used on an umbilical if required or located in the control position 14 of the machine, includes two sets of pushbuttons with LED (light emitting diode) indicators 69, and two spring-centred joysticks, 70, 71 each 8-way and centre 'off'.

The first row of pushbuttons is used to select one of four mutually exclusive electronic control modes labelled "MANUAL", "LEARN" (corresponding to the teaching runs referred to above), "HOME" and "RUN", while the second row is used to select one of three mutually exclusive coupling modes for the booms labelled "LEFT-HAND MASTER", "INDEPENDENT" and "RIGHT-HAND MASTER".

Selection of either the "MANUAL" or "LEARN" pushbuttion in combination with any of the three coupling modes enables the booms to be "manually" controlled by means of the joystick controls 70, 71 via the control circuit 61.

In the cardinal joystick positions, with the INDEPENDENT MODE selected; the appropriate camshafts are rotated under the control output signals 73 to 74 of the circuit 61 to produce corresponding simple left/right or up/down movement of the associated boom. For example, in the simple right (or left) position of the left-hand joystick 70, a signal from output 73 of the circuit 61 will cause the camshaft controlling the axis of movement of the left-hand boom to rotate to the +120° (−120°) position (Figure 4) causing the boom to move left (or right) at a fixed cutting speed represented by maximum (1-1/2 units) power.

In the intermediate "45°" positions of the joysticks, signals will appear at both outputs 73, 74 of circuit 61 causing the associated camshaft to rotate to their +80° positions at which the flow to each ram is restricted to 2/3 maximum power (1 unit) such that the resultant speed of movement of the boom is substantially the same as for simple up/down or left/right movement. The boom will move diagonally upwards and to the right.

In the central OFF position of the joysticks, the direct manual control of the machine can be made to function to provide rapid boom positioning since more hydraulic power is available in this fully manual mode.

Thus, selection of the INDEPENDENT mode enables both booms to be independently controlled by the two joysticks 70, 71. In either of the LEFT or RIGHTHAND Master modes, one of the booms is selected as the "master" and the joystick control for the other boom is disabled. Under single joystick control of the selected "master" boom, the other "slave" boom moving at "normal" cutting speed, mirrors the movements of the master boom by taking up a mirror image position.

Thus, both booms are driven mirror-wise off a

single joystick until the INDEPENDENT coupling mode is selected again.

The LEARN mode differs from the MANUAL mode in that during the LEARN mode, information received from the boom position sensors 65 to 68 is stored within the control unit 61 to provide a memorised record of the paths of movement and relative positions of each of the two booms occurring whether under electronic joystick control or rapid direct manual control, during the LEARN mode. Before switching to the LEARN mode, however, the booms are normally moved to an initial starting or HOME position, (which is usually a "mirror-image position") for example the normal sumping-up position using the MANUAL control mode.

The LEARN mode is then selected and the positions at which the booms stand on selection of this mode are recorded as their HOME positions. The operator then controls the movements of the boom using the joysticks 70, 71 in any one or a sequential combination of the three coupling modes, as well as direct high-speed manual control if desired, to follow a desired cutting path. On completion of this "teaching run", the operator may press either the MANUAL or HOME pushbuttons. In the latter case, the booms will automatically return to their recorded PARK positions and this movement home will be recorded as part of the information learned in the LEARN mode, i.e. teaching run.

The RUN mode can only be entered from the PARK mode, i.e. to ensure that the booms are correctly positioned at their stating points, whereupon the learned sequence of movements is automatically repeated at the maximum speed (within the constraints of the limited power available during "electronic" control) compatible with maintaining the same relative positions of the booms as when the sequence was entered in the LEARN mode. Thus, during the RUN mode, the actual and relative positions of the two booms, as detected by the real-time signals received from the sensors 65 to 68 are continuously compared with the stored information relating to the desired paths of the booms, and if a discrepancy arises, for example when one of the booms is slowed by hard rock, the other boom will be slowed to maintain the desired relative positions. This is achieved by causing the relevant chamshaft(s) to rotate back to a position in which reduced power is applied to the hydraulic rams concerned. In addition, the power consumed by either one of the cutting head drive motors as sensed by the sensors 62, 63 the relevant boom is slowed down in the same way until the power consumed by the motor is reduced to an acceptable level.

If during the LEARN mode both booms are left stationary, for example, while the operator is deciding on his next cut, or is waiting for dust to clear, this will not result in any delay during the RUN mode. However, if during the LEARN mode, one boom is parked or held stationary while the other boom is moved in the INDEPENDENT mode, e.g. to remove material in the central boom overlap region, this will of course be repeated during the RUN mode. The RUN mode can at any time be terminated by entering MANUAL or HOME modes, but can then only be re-entered from the HOME positions.

It should be noted that the boom coupling mode is only important when in the MANUAL or LEARN modes. The LED's for this mode are therefore extinguished when in the HOME or RUN modes.

Should the memory capacity of the circuit 61 be exceeded during the LEARN mode, the MANUAL mode will be automatically re-entered.

The fast movement capability under power of the pumps P1 and P2 is only available of course via the direct manual joystick controls of the machine, and is not accessible for control via the electronic control circuit of Figure 5. As already explained, if direct manual control is used during the LEARN mode, the path will be "remembered" but can only be repeated at normal cutting speed during the RUN mode.

An important advantage of the preferred embodiment of the invention is that the entire system may be interposed between the hydraulic circuitry and joysticks of an already existing road-header machine. Thus while the invention may form part of the original equipment of a newly manufactured road-header, it may also be added to a previously made road-header by relatively simple means not involving any appreciable or drastic modification of the hydraulics of the existing machine.

Claims

1. Automatic electronic control means for a hydraulic boom which includes a hydraulic control circuit, the said electronic control means including means for storing information relating to a desired path of movement of the boom, and means for automatically controlling the movement of the boom in accordance with the stored information by means of mechanically operated hydraulic control valves connected in use in the said hydraulic control circuit of the boom.

2. Means according to claim 1, wherein the said mechanically operated hydraulic control valves are solenoid-actuated or proportional valves controlled by electrical signals from the control means.

3. The means according to claim 1 or claim 2 in combination with a hydraulic boom which includes a first portion pivotally mounted on a support for rotation about a first axis, and a second portion pivotally mounted on the first portion for rotation about a second axis perpendicular to the first.

4. The combination according to claim 3, wherein the first portion comprises a turret pivotable about a vertical axis, and said second portion comprising a jib portion pivotable relative to the turret about a horizontal axis.

5. The combination according to claim 3 or 4,

wherein the said hydraulic control circuit for the boom includes means for independently controlling the pivotal movements of the first and second portions thereof about their respective axes.

6. The combination according to claim 5, wherein the automatic control means includes two mechanically operated hydraulic control valves connected in the said hydraulic control circuit of the boom for controlling the movements of each of the two boom portions, one for each direction of movement of that boom portion about its respective axis.

7. The combination according to claim 6, wherein one or more further mechanically operated control valves are included for controlling the speed of movement of each boom portion about its axis.

8. The combination according to any of claims 3 to 7, wherein the mechanically operated hydraulic control valves for each of the first and second portions of the boom are controlled by solenoids, or by proportional valves, or are controlled by a respective bank of cams mounted on a common camshaft.

9. The control means or said combination according to any preceding claim, wherein the control means is adapted for the co-ordinated control of two or more booms, for example in a multiple-boom road-header or tunnel cutting machine, and the said stored information comprises information relating to the desired paths of movement of each boom, and optionally also the desired relative positions of the booms or of pairs of booms, during such movements.

10. The control means or said combination according to claim 9, further including means for monitoring the positions of the or each boom, and feed-back means for comparing the actual position of the boom(s), as sensed by said monitoring means, with the desired position of the booms as determined by the stored information, whereby to control the movement of the boom(s) to maintain correspondence between the actual and desired boom positions.

11. The control means or combination according to any preceding claim, further including means for deriving said stored information by monitoring the movements of the boom(s) during a 'teaching run' and storing information relating to the boom positions during the teaching run, whereby the boom(s) may be controlled to repeat a desired cutting path selected by the operator during the teaching run.

12. A combination according to claim 11 for use with a multiple boom machine, wherein two or more booms are automatically controlled from stored information derived from a teaching run using only one boom.

13. The combination according to claim 12, wherein a pair of booms are made to follow mirror image paths using information derived from the teaching run using only one boom.

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